Chapter 1 Introduction

Pollution from Stormwater can Cause:

- Destruction of fish, wildlife and aquatic habitats
- Beach closures
- Loss in aesthetic value
- Higher cost for, or loss of, drinking water supply

Stormwater runoff has been identified as a leading cause of pollution to surface water bodies. As precipitation falls onto land, some of it infiltrates into the ground to recharge groundwater, while a portion of it flows across the land (runoff) where it is directly discharged into surface water bodies. As the level of development increases, impervious areas generally increase. With greater imperviousness comes greater stormwater runoff. Pollutants on the land are then carried by the stormwater runoff into nearby surface waters.

Photo courtesy of Center for Water Protection.

Health risks associated with stormwater pollution have forced the closure of many beaches and waterways like the one shown above.

The Maine Department of Environmental Protection (DEP) recognizes the importance of controlling stormwater to preserve the State's natural resources. This manual was developed to assist communities, watershed groups, individuals, engineers and developers in understanding stormwater impacts and to select appropriate Best Management Practices (BMPs) to control stormwater from development in accordance with Maine DEP's Stormwater Management regulations, Chapter 500.

Volume I of this manual provides background information on the effects of urbanization and stormwater runoff and outlines Maine DEP's objectives and some techniques that can be implemented by anyone to control stormwater runoff.

Section Contents:

1.1 Past Stormwater Management Practices

The design of stormwater management has evolved over the last 100 years. The first efforts at controlling stormwater, often previously called "drainage", were made by engineers and farmers with the goal of draining wet areas to make them more useable. While it must have seemed practical at the time, this was the first step in creating the current dilemma of excess stormwater and flooding. In addition fill adding took up flood plain and flood storage volume, pushing flood flows downstream.

As flooding increased, early piped drainage systems simply rerouted runoff downstream. Unfortunately, these downstream areas would receive higher flood levels than they ever had prior to the development of drainage projects, since the water still had to go somewhere.

Flood control projects grew in size as the population grew. As development occurred, larger and larger pipes, canals and lined concrete channels were needed to move the water out as quickly as possible.

Under the authority of the Clean Water Act, point sources of pollution such as industrial discharges and municipal waste treatment plants were increasingly more stringently regulated, yet fishable/swimmable water quality goals set in 1972 were not met within the original twenty year timeframe. In the late 1980s, federal and university scientists began to understand the water quality problem that had been created by past drainage engineering and land use practices. The identified reason was non-point sources or stormwater.

Since the late 1980s, the impact of stormwater on water quality has become clearer with continued research and effort. However, it has only recently been clearly recognized that flooding and other water quantity issues such as groundwater declines and losses in stream baseflow are also due to how stormwater is managed.

Urbanization causes changes in the hydrology of an area's:

- Peak flow characteristics,
- Total runoff volume,
- Water quality,
- Aesthetic character of the hydrologic system.
- Drainage areas because of land grading, and
- Base flow.

As urbanization and suburbia spread, major changes in stormwater quantity and quality occur. Developed areas reduce groundwater recharge by dramatically increasing imperviousness. Impervious surfaces prevent water from infiltrating into the groundwater, and cause water to rapidly flow off surfaces, picking up pollutants as it travels to the nearest surface water. The pollutant concentrations in stormwater are also much higher along with the greater volume of runoff.

1.2 Water Quantity

Development interferes with the natural hydrologic cycle. In a natural hydrologic cycle, a portion of the precipitation goes back into the atmosphere through evaporation and transpiration (evapotranspiration); a portion infiltrates into the ground, where it is able to recharge groundwater flows and provide baseflows for streams, and lastly a portion runs off over the surface of the land and is discharged into nearby surface waters. In urbanized areas, these three components still occur but the runoff portion is greatly increased at the expense of the infiltration portion. Figure 1-1 illustrates the effects of development on the water budget.

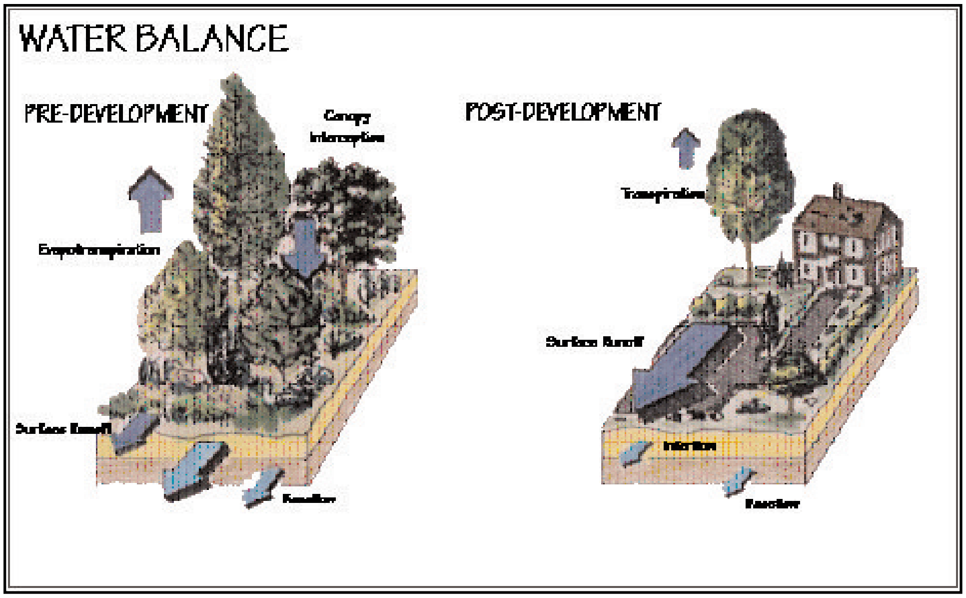

Figure 1-1. Effects of Development on the Water Budget

As the land is covered with impervious surfaces such as roads, buildings, and parking lots, the amount of rainfall that can infiltrate into the soil is reduced, thereby increasing the volume of surface runoff from the watershed. Typical impervious cover percentages are shown in Table 1-1. Impervious surface also reduce evapotranspiration, as the trees and vegetation that contribute to this process are removed and replaced with paved surfaces. Figure 1-2 shows the relationship of runoff, infiltration, and evaporation for watersheds with varying degrees of impervious cover.

Table 1-1
Typical Impervious Area Percentages
(MPCA, 1989 modified by Maine DEP)

LAND USE	% IMPERVIOUS COVER
Business District or Shopping Center	95-100
Residential, High Density (lots 1/2 acre or less)	30-60
Residential, Medium Density (lots less than 3 acres but greater than 1/2 acre)	10-40
Residential, Low Density (lots greater than 3 acres)	8-15
Open Areas	0-5

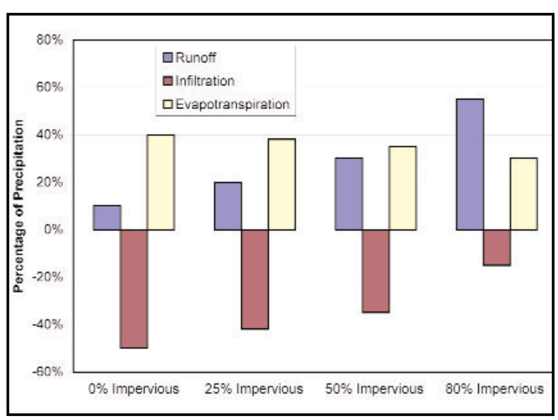

Figure 1-2. Relationship Between Infiltration, Runoff, Evapotranspiration and Imperviousness

As urban areas develop, natural drainage patterns are modified, with runoff channeled into road drainage ditches, storm sewers, and paved channels. These modifications increase the velocity of runoff, which decreases the time required to convey it to the nearest surface water. Greater volumes of water reach streams and rivers faster, resulting in excessive peak volumes and floods. Figure 1-3 shows typical pre- and post-development hydrographs. As shown on the figure, natural pre-development runoff slowly seeps into the ground over a period of days, with slow release to surface waters. The post-development peaks are much higher since the water turns into surface runoff and hits the receiving water body at once.

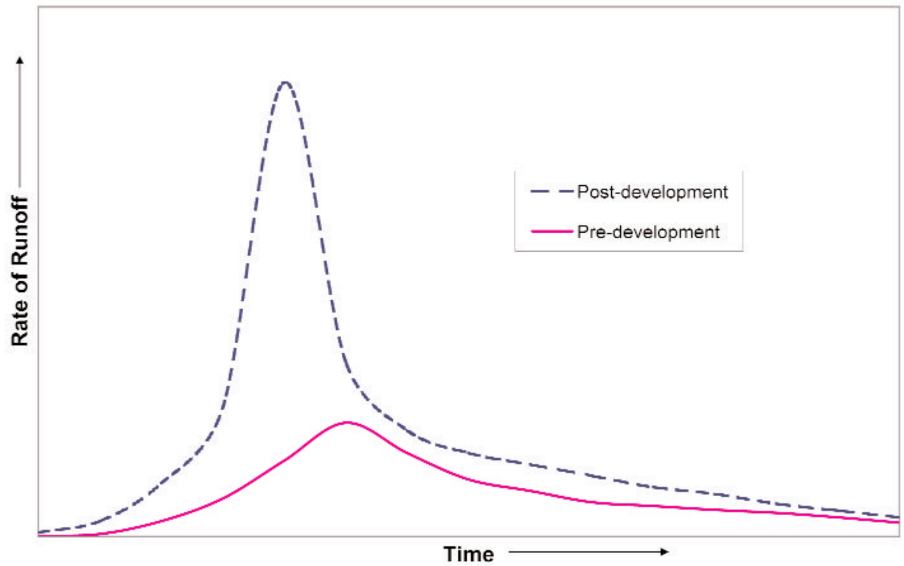

Figure 1-3. Typical Stormwater Runoff Hydrograph Pre and Post Development

Figure 1-4 shows the impacts of development on flooding frequencies. A developed watershed can increase flows from 550 cfs in a forested state to over 3000 cfs in a developed, highly impervious state, a dramatic and frightening increase. Increased streamflows also leads to erosion of natural streambanks and widening of the stream channel to handle the larger flow volumes during frequent storm events. This increases sediment loadings to the streams and exposes plant roots along the banks.

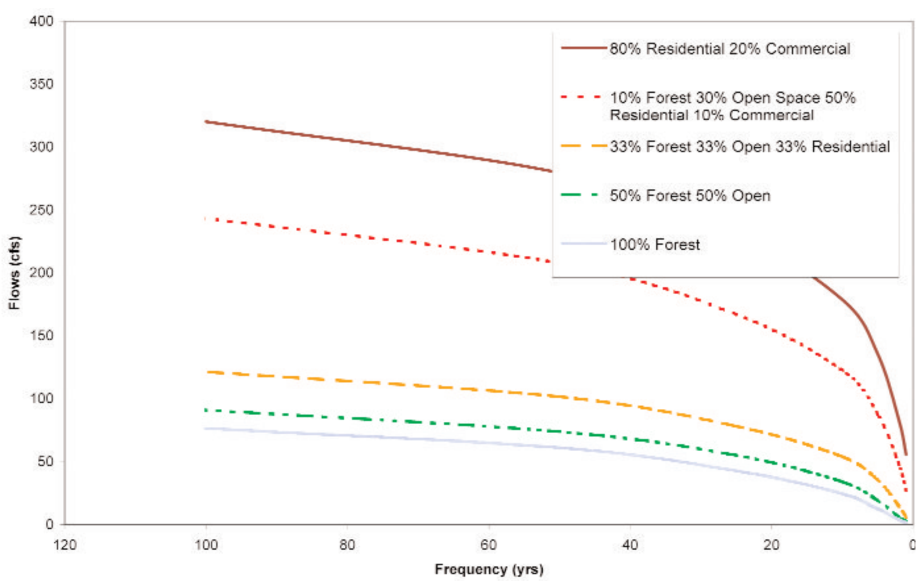

Figure 1-4. Effects of Development on Flooding Magnitude and Frequency

In addition to flooding, increased runoff due to development can tax the hydraulic capacity and stability of downstream channels and structures, and cause the lowering of the groundwater table. The stream channel is exposed to erosive and destabilizing flows much more frequently than under natural conditions, thus resulting in loss of bottom dwelling organisms with longer life cycles that rely on relatively stable habitat. The groundwater table decline can affect the yield of drinking water supplies and also reduces the discharge of clean water to streams (baseflow). Baseflow is needed to maintain streamflows during summer periods, when there is less precipitation. These changes in hydrology, combined with increased pollutant loading, can have a dramatic effect on the aquatic ecosystem in urban streams.

Increased streamflow volumes and velocities associated with urban impacts have resulted in significant erosion of streambanks, as shown here in Bangor, Maine.

1.3 Water Quality

The photo above shows runoff from a developed area entering a municipal storm drain system. If not managed properly, increased runoff can flood local roads and waterways, as the capacity of drainage structures and natural channels are taxed.

Development also impacts the water quality of streams, ponds, lakes and wetlands. As impervious area increases, the volume and velocities of stormwater increase, often resulting in erosion of soils. Pollutant deposits on the land surface also increase as the intensity of land use increases. In a forested or other undeveloped area, many ongoing physical, chemical, and biological processes interact to trap, immobilize, decompose or otherwise alter most of the dissolved and suspended materials found in the runoff. As human land use intensifies, these natural biological and chemical processes are disrupted and pollutants build up as more are added to the land surface (i.e., pesticides, fertilizers, animal wastes, oil, grease, heavy metals). These materials are then washed off by rain and runoff, increasing the pollutant load to receiving waters. Figure 1-5 shows the increase in sediment and phosphorus loadings in agricultural and urban settings compared to a forested setting.

Some of the typical urban pollutants and their impacts are summarized in Table 1-2 and discussed further below.

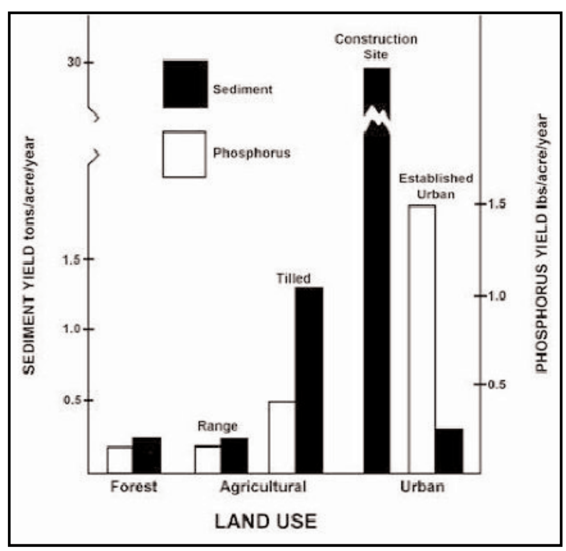

Figure 1-5. Land use affects on the quality of runoff water

Table 1-2. Summary of Urban Non-point Source Pollutants			
	Contaminants	**Sources**	**Impacts**
Nutrients	• Phosphorus • Nitrogen	• Urban landscape runoff (fertilizers, detergents, plant debris, sediment, dust, gasoline, tieres, septic system effluent) • Agricultural runoff (fertilizers, animal waste)	• Increased algal growth & turbidity • Decreased dissolved oxygen (DO) • Limited recreational values • Reduction of animal habitat
Solids	• Sediment • Floatables	• Construction sites & other disturbed/non-vegetated lands • Road & parking lot sanding • Agricultural lands • Eroding stream banks • Animal waste	• Decreased storage capacity • Destruction of benthic habitat • Interference with animal respiration & digestion • Reduced aesthetic value
Pathogens	• Bacteria • Viruses	• Septic systems • Illicit sewage connections	• Shellfish bed closures • Beach closures • Contamination of drinking water
Thermal Impacts	• Temperature changes from urbanization	• Paved & open areas that absorb heat • Reduction of shade trees • BMPs (shallow ponds and swales	•Reduced sensitive stream insects and fish species
Hydrocarbons	• Oil & grease • Polycyclic aromatic hydrocarbons (PAHs)	• Parking lots & roadways • Spills, Oil leaks & auto emissions • Illicit sewage connections • Illegal dumping of waste oil	• Degraded appearance of water surfaces • Lowered DO • Degradation of fisheries
Toxic Organics	• Pesticides • Polychlorinated biphenyls	• Indoor & outdoor use • Industrial activities • Illicit sewage connections	• Loss of sensitive animal species and fisheries • Reproductive & behaviorial problems from accumulation in food chain
Acids	• Nitrate (NO_3) • Sulfite (SO_2) • Anions HNO_3, HSO_2/H_2SO_4 that form in the air	• Incomplete combustion process coupled with atmospheric reactions (acid rain)	• Loss of sensitive animal species and fisheries • May affect mobility, availability & toxicity of metals & other toxins
Humic Substances	• Plant materials (grass clippings & leaves)	• Urban & surburban landscapes	• Degraded fisheries
Salt	• Sodium • chloride	• Road salt storage areas • Roadway & parking areas	• Loss of sensitive animal species and fisheries • Contaminated surface and ground waters
Metals	• Heavy metals (lead, copper, cadmium, zinc, mercury & chromium)	• Industrial activities & waste • Illicit sewage connections • Asphalt & atmospheric deposition • Automobile wear & exhaust & fluid leaks • Leaching water supply and stormwater delivery systems	• Accumulation in animal tissue that could be ingested by humans

Nutrients

Water quality is largely impacted by nutrient inputs, particularly nitrogen and phosphorus. Phosphorus is typically the primary nutrient of concern in freshwater systems, with nitrogen a secondary concern. Nitrogen is usually more important in saltwater systems. These key nutrients are largely responsible for eutrophication of waterbodies – the gradual increase in nutrient inputs to a waterbody over time, causing excessive plant growth (algae). The increased algal growth can also contribute to greater turbidity and lower dissolved oxygen concentrations, which can promote the release of other substances (pollutants) into the water column. In some cases, algal blooms may occur causing the growth of billions of algae to color the water green and release strong odors as they decay. Phosphorus is readily removed if filtered through soils, as it has a tendency to stick to particles. However, carried by stormwater either in a dissolved form or attached to small particles, it quickly enters the waterbody and accelerates eutrophication.

This waterway is experiencing excessive algae blooms due to nutrient inputs from stormwater.

Solids – Sediment and Floatables

Solid contaminants include sediment and floatable wastes. Large deposits of sediment are often seen with construction sites, where erosion controls are not properly installed. High velocity stormwater easily erodes and picks up sediments from disturbed areas. It also comes from sanding practices and is carried through the storm drain network. Sediment deposits can fill in the waterbody, smother benthic invertebrates, increase turbidity (which in turn affects fish and other organisms), and contribute other pollutants in that many pollutants have a tendency to stick to sediment particles. Floatables are also a concern as they may be collected and deposited into waterbodies from street litter and careless disposal practices.

The best approach to control sedimentation is to implement erosion controls to prevent the production and transport of sediment to waterways. Sediment can also be intercepted in stormwater and allowed to settle.

This parking area contributes sediment to the storm drain network, where it will be carried to the nearest surface water. The sediment contains many pollutants that are deposited through air pollution or directly by cars, as these have a tendency to stick to the sediment particles. Sediments fill in waterbodies, providing a substrate for aquatic weed growth, and can have an adverse effect on fish and other organisms.

Pathogens

Pathogens are responsible for many beach closures, shellfish bed closures and the contamination of drinking water. Pathogens are often associated with storm events, due to bacteria that enters the water course from runoff over land that has deposited pet and livestock wastes, septic overflows, sewer surcharges or exfiltration and wastes from other animals. Testing over the years has shown huge quantities of pathogenic bacteria, viruses and protozoans often rivaling those found in slightly diluted sewage. Pathogens can cause human diseases, including gastroenteritis, giardiaris and cryptosporidiosis, among others. Filtration through soils is generally the best method to remove pathogens from stormwater.

Thermal Impacts

Pavement and other impervious surfaces tend to absorb substantial amounts of heat in summer due to their dark coloring and typically a lack of shade. This heat is transferred to runoff passing over the surface, resulting in runoff that is dramatically warmer than natural groundwater inflow would have been under a natural hydrologic cycle. Some BMPs, such as shallow ponds and swales, can also increase the temperature of runoff before it is discharged, as it is quickly warmed on hot summer days before being discharged. Temperature changes can be stressful and even lethal to many coldwater organisms. A rise in water temperature of just a few degrees Celsius over ambient conditions can reduce or eliminate sensitive stream insects and fish species such as stoneflies, mayflies and trout (Schueler, 1987).

Hydrocarbons

Hydrocarbons are a common contaminant associated with development. They are generally related to transportation in that they are washed off roadways, parking lots and other impervious surfaces after being deposited there by auto emissions, oil leaks and spills. Hydrocarbons are toxic to animal species at low concentrations and can degrade fisheries habitats.

This oil sheen, left by parked vehicles, makes its way towards this catch basin and storm drain network. Without proper treatment, the oil will enter the nearest surface water, where it will degrade fisheries habitats.

Toxic Organics

Toxic organics, such as pesticides and polychlorinated biphenyls (PCBs), may be found in stormwater due to industrial activities and illicit sewage connections. Toxic organics may cause the loss of sensitive animal species and fishery resources, and often accumulate through biomagnification in the food chain causing reproductive and behavioral problems that can ultimately affect human health through ingestion of the fish and animal species.

Acids

Acids may enter stormwater through incomplete combustion processes coupled with atmospheric reactions (acid rain). Acidic contamination can cause loss of sensitive animal species and fishery resources, and may increase the mobility, availability, and toxicity of metals and other toxins.

Humic Substances

Humic substances include decomposing plant materials such as grass clippings and leaves that can be picked up in stormwater and carried into a waterbody. Increased loading of organic materials into water bodies uses oxygen to finish the decomposition of the materials. This lowers dissolved oxygen levels, which can in turn cause the release of other substances (pollutants) into the water column. Oxygen concentrations may ultimately be reduced below levels needed to support aquatic life. These contaminants can degrade fishery resources and reduce fish populations.

Leaves that enter the storm drain network are carried into receiving waters, where they use dissolved oxygen to decompose. Reduced dissolved oxygen levels in the water threaten aquatic life that need the oxygen to live.

Uncovered salt piles can be picked up by runoff and carried to surface waters, where it is toxic to freshwater organisms.

Salt

Salt is often contained in stormwater due to winter salting practices and road salt storage.

Salt is toxic to freshwater organisms and can reduce fishery resources. Salt can also stress plant species. Normal application of salt to roads for deicing is unlikely to create toxic conditions due to elevated chloride levels; however, there have been numerous documented cases of surface and ground water contamination caused by runoff from inadequately protected stockpiles of salt and sand salt mixtures (MPCA, 1989). Contamination of wells due to salt application on roads is well documented.

Metals

Metals are commonly seen in stormwater due to industrial activities, atmospheric deposition and from transportation related activities (i.e., asphalt, automobile wear, exhaust). The most abundant heavy metals in stormwater are lead, zinc and copper, which together account for about 90% of the dissolved heavy metals and 90-98% of the total metal concentrations. Metals increase toxicity of runoff and accumulate in the food chain. Many metals can be removed from stormwater through settling of sediments, as they tend to stick to sediments.

Selected References

MPCA, 1989. *Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota.* Minnesota Pollution Control Agency, Division of Water Quality, St. Paul, Minnesota.

Schueler, T.R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Metropolitan Washington Council of Governments, Washington, D.C.